

## New Model Army Soldier Rolls Closer to Battle

nytimes.com

### Correction Appended

The American military is working on a new generation of soldiers, far different from the army it has.

"They don't get hungry," said Gordon Johnson of the Joint Forces Command at the Pentagon. "They're not afraid. They don't forget their orders. They don't care if the guy next to them has just been shot. Will they do a better job than humans? Yes."

The robot soldier is coming.

The Pentagon predicts that robots will be a major fighting force in the American military in less than a decade, hunting and killing enemies in combat. Robots are a crucial part of the Army's effort to rebuild itself as a 21st-century fighting force, and a \$127 billion project called Future Combat Systems is the biggest military contract in American history.

The military plans to invest tens of billions of dollars in automated armed forces. The costs of that transformation will help drive the Defense Department's budget up almost 20 percent, from a requested \$419.3 billion for next year to \$502.3 billion in 2010, excluding the costs of war. The annual costs of buying new weapons is scheduled to rise 52 percent, from \$78 billion to \$118.6 billion.

Military planners say robot soldiers will think, see and react increasingly like humans. In the beginning, they will be remote-controlled, looking and acting like lethal toy trucks. As the technology develops, they may take many shapes. And as their intelligence grows, so will their autonomy.

The robot soldier has been a dream at the Pentagon for 30 years. And some involved in the work say it may take at least 30 more years to realize in full. Well before then, they say, the military will have to answer tough questions if it intends to trust robots with the responsibility of distinguishing friend from foe, combatant from bystander.

Even the strongest advocates of automatons say war will always be a human endeavor, with death and disaster. And supporters like Robert Finkelstein, president of Robotic Technology in Potomac, Md., are telling the Pentagon it could take until 2035 to develop a robot that looks, thinks and fights like a soldier. The Pentagon's "goal is there," he said, "but the path is not totally clear."

Robots in battle, as envisioned by their builders, may look and move like humans or hummingbirds, tractors or tanks, cockroaches or crickets. With the development of nanotechnology -- the science of very small structures -- they may become swarms of "smart dust." The Pentagon intends for robots to haul munitions, gather intelligence, search buildings or blow them up.

All these are in the works, but not yet in battle. Already, however, several hundred robots are digging up roadside bombs in Iraq, scouring caves in Afghanistan and serving as armed sentries at weapons depots.

By April, an armed version of the bomb-disposal robot will be in Baghdad, capable of firing 1,000 rounds a minute. Though controlled by a soldier with a laptop, the robot will be the first thinking machine of its kind to take up a front-line infantry position, ready to kill enemies.

"The real world is not Hollywood," said Rodney A. Brooks, director of the Computer Science and Artificial Intelligence Laboratory at M.I.T. and a co-founder of the iRobot Corporation. "Right now we have the first

few robots that are actually useful to the military."

Despite the obstacles, Congress ordered in 2000 that a third of the ground vehicles and a third of deep-strike aircraft in the military must become robotic within a decade. If that mandate is to be met, the United States will spend many billions of dollars on military robots by 2010.

As the first lethal robots head for Iraq, the role of the robot soldier as a killing machine has barely been debated. The history of warfare suggests that every new technological leap -- the longbow, the tank, the atomic bomb -- outraces the strategy and doctrine to control it.

"The lawyers tell me there are no prohibitions against robots making life-or-death decisions," said Mr. Johnson, who leads robotics efforts at the Joint Forces Command research center in Suffolk, Va. "I have been asked what happens if the robot destroys a school bus rather than a tank parked nearby. We will not entrust a robot with that decision until we are confident they can make it."

Trusting robots with potentially lethal decision-making may require a leap of faith in technology not everyone is ready to make. Bill Joy, a co-founder of Sun Microsystems, has worried aloud that 21st-century robotics and nanotechnology may become "so powerful that they can spawn whole new classes of accidents and abuses."

"As machines become more intelligent, people will let machines make more of their decisions for them," Mr. Joy wrote recently in Wired magazine. "Eventually a stage may be reached at which the decisions necessary to keep the system running will be so complex that human beings will be incapable of making them intelligently. At that stage, the machines will be in effective control."

Pentagon officials and military contractors say the ultimate ideal of unmanned warfare is combat without casualties. Failing that, their goal is to give as many difficult, dull or dangerous missions as possible to the robots, conserving American minds and protecting American bodies in battle.

"Anyone who's a decision maker doesn't want American lives at risk," Mr. Brooks said. "It's the same question as, Should soldiers be given body armor? It's a moral issue. And cost comes in."

Money, in fact, may matter more than morals. The Pentagon today owes its soldiers \$653 billion in future retirement benefits that it cannot presently pay. Robots, unlike old soldiers, do not fade away. The median lifetime cost of a soldier is about \$4 million today and growing, according to a Pentagon study. Robot soldiers could cost a tenth of that or less.

"It's more than just a dream now," Mr. Johnson said. "Today we have an infantry soldier" as the prototype of a military robot, he added. "We give him a set of instructions: if you find the enemy, this is what you do. We give the infantry soldier enough information to recognize the enemy when he's fired upon. He is autonomous, but he has to operate under certain controls. It's supervised autonomy. By 2015, we think we can do many infantry missions.

"The American military will have these kinds of robots. It's not a question of if, it's a question of when."

Meanwhile, the demand for armed bomb-disposal robots is growing daily among soldiers in Iraq. "This is the first time they've said, 'I want a robot,' because they're going to get killed without it," said Bart Everett, technical director for robotics at the Space and Naval Warfare Systems Center in San Diego.

Mr. Everett and his colleagues are inventing military robots for future battles. The hardest thing of all, robot designers say, is to build a soldier that looks and acts human, like the "I, Robot" model imagined by Isaac

Asimov and featured in the recent movie of the same name. Still, Mr. Everett's personal goal is to create "an android-like robot that can go out with a soldier to do a lot of human-like tasks that soldiers are doing now."

A prototype, about four feet high, with a Cyclops eye and a gun for a right arm, stood in a workshop at the center recently. It readied, aimed and fired at a Pepsi can, performing the basic tasks of hunting and killing. "It's the first robot that I know of that can find targets and shoot them," Mr. Everett said.

His colleague, Jeff Grossman, spoke of the evolving intelligence of robot soldiers. "Now, maybe, we're a mammal," he says. "We're trying to get to the level of a primate, where we are making sensible decisions."

The hunter-killer at the Space and Naval Warfare Systems Center is one of five broad categories of military robots under development. Another scouts buildings, tunnels and caves. A third hauls tons of weapons and gear and performs searches and reconnaissance. A fourth is a drone in flight; last April, an unmanned aircraft made military history by hitting a ground target with a small smart bomb in a test from 35,000 feet. A fifth, originally designed as a security guard, will soon be able to launch drones to conduct surveillance, psychological warfare and other missions.

For all five, the ability to perceive is paramount. "We've seen pretty dramatic progress in the area of robot perception," said Charles M. Shoemaker, chief of the Army Research Laboratory's robotics program office at Aberdeen Proving Grounds in Maryland. That progress may soon allow the Army to eliminate the driver of many military vehicles in favor of a robot.

"There's been almost a universal clamor for the automation of the driving task," he said. "We have developed the ability for the robot to see the world, to see a road map of the surrounding environment," and to drive from point to point without human intervention. Within 10 years, he said, convoys of robots should be able to wend their way through deep woods or dense cities.

But the results of a road test for robot vehicles last March were vexing: 15 prototypes took off across the Mojave Desert in a 142-mile race, competing for a \$1 million prize in a Pentagon-sponsored contest to see if they could navigate the rough terrain. Four hours later, every vehicle had crashed or had failed.

All this raises questions about how realistic the Army's timetable is for the Future Combat Systems, currently in the first stages of development. These elaborate networks of weapons, robots, drone aircraft and computers are still evolving in fits and starts; a typical unit is intended to include, say, 2,245 soldiers and 151 military robots.

The technology still runs ahead of robot rules of engagement. "There is a lag between technology and doctrine," said Mr. Finkelstein of Robotic Technology, who has been in the military robotics field for 28 years. "If you could invade other countries bloodlessly, would this lead to a greater temptation to invade?"

Colin M. Angle, 37, is the chief executive and another co-founder of iRobot, a private company he helped start in his living room 14 years ago. Last year, it had sales of more than \$70 million, with Roomba, a robot vacuum cleaner, one of its leading products. He says the calculus of money, morals and military logic will result in battalions of robots in combat. "The cost of the soldier in the field is so high, both in cash and in a political sense," Mr. Angle said, that "robots will be doing wildly dangerous tasks" in battle in the very near future.

Decades ago, Isaac Asimov posited three rules for robots: Do not hurt humans; obey humans unless that violates Rule 1; defend yourself unless that violates Rules 1 and 2.

Mr. Angle was asked whether the Asimov rules still apply in the dawning age of robot soldiers. "We are a long ways," he said, "from creating a robot that knows what that means."

**ARSENAL OF THE FUTURE** This is the second article of a series that is periodically examining weapons of the future. The previous article is at [nytimes.com/business](http://nytimes.com/business).

Correction: February 25, 2005, Friday A front-page article on Feb. 16 about the military's efforts to build robot soldiers misstated the third rule for robots from "I, Robot," by the science-fiction author Isaac Asimov, a guideline for their coexistence with humans. (Asimov's first two rules were "Do not hurt humans" and "Obey humans unless that violates Rule 1.") His third rule was, "Defend yourself unless that violates Rule 1 OR Rule 2" -- not "Rule 1 AND Rule 2."